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## THE GROWING PLANT AND SOIL MICRO-ORGANISMS *

Relationships between plants and the nature and distribution of soil organisms are proving to be of much interest. The presence of roots in soil causes marked changes in the activities of micro-organisms, in their numbers and species, especially in the zone of soil in close proximity to the root, *i.e.*, the rhizosphere. Evidence of highly specific interrelations between the plant and microbial species is afforded by the work of M. B. Linford (1) who shows that in the rhizosphere of young roots bacteria are present in large numbers from the crown down to the apical meristem, in which zone the population of protozoa and micro-phagus nematodes becomes notably high. According to R. L. Starkey (2) the population is particularly dense on the actual surface of the root. The influence of the plant on soil organisms may result from a variety of causes, *e.g.*, addition of decaying organic matter in the form of sloughed-off epidermal material of the root, excretion of substances, beneficial or otherwise, from the plant system, changes in carbon dioxide-oxygen balance in the soil atmosphere, or in soil reaction, modification of water status or of mineral nutrient supply by competition of the plant or in soil temperature by shading. Each of these factors is known to affect the activity of micro-organisms and probably contributes to the existence of a rather specialised distribution of species in the rhizosphere. Conversely the biological balance in the rhizosphere probably effects changes in nutrient supply notably of available nitrogen and phosphate, to the plant. Some such nutrient inter-relationships between micro-organisms and plants are already known, *e.g.*, the microbial " lock-up " of available nitrogen by cellulose-decomposing organisms, and others are in process of examination. It may well be that with further advancement of our knowledge of these relationships, considerations of soil microbiology may rank with those of manuring or of cultural operations in agricultural practice. In some cases doubtless at least some species of organisms may have to be placed in the same category as weeds, viz., competitors with the plant for the vital nutrients of the soil. On the other hand one may well anticipate the existence between plant and micro-organisms of many forms of

* Abstracted from the section on "Soils and Fertilisers" by A. G. Pollard, B.SC., F.R.I.C., Reports of the Progress of Applied Chemistry for 1943, issued by the Society of Chemical Industry, London.

co-operative action, the classic example of which is the highly perfected symbiotic relationship between leguminous plants and the nodule organisms.

The actual mechanism of these interrelations affords a fascinating subject of research, but as yet it can scarcely be assumed that we have passed beyond the fringe of the problem. The multiplicity of factors involved must inevitably lead to slow progress. The influence of the plant on soil organisms is largely characteristic of the plant species and appears to be only of a temporary character in arable soils. The effects become accentuated and stabilised when the surface vegetation is of a more permanent type. Vandecaveye and Katznelson (2A) record higher bacterial and smaller fungal populations in grass land than in forest soils. This appears to be related to the more rapid and complete humification under grass. Although no relationship is apparent between the total nitrogenous matter content of soil and bacterial numbers, it seems clear that the nature of the organic matter, the stage of its decomposition, and the relative ability of the species to utilise the products of decomposition (3) are important factors in the survival and reproduction of particular species. On arable soils N. James and M. L. Sutherland (4) find somewhat higher bacterial numbers under wheat than on fallow areas and M. G. Tiagni-Riadno (5) shows that in soils bearing a lucerne crop over 2-4 years the microbial population was much greater and more varied than in those which had been under annual cultivation for a long period.

Whatever may be the gross effect of plant-micro-organism associations on the nutritional regime of each, it is clear that the distribution of individual species of organisms in soil is often dependent on the competition for available nutrients. J. L. Stokes (6) observes that the earlier stages of the decomposition of organic matter in soil are associated with conditions favourable to the development of bacteria and actinomyces, but unsuitable for algae; the latter increased at a later stage when bacterial activity slackened. Following up earlier studies (7) of bacterial equilibria in soils and the influence on them of plant growth, A. G. Lochhead and F. E. Chase (8) classify soil bacteria into two principal groups between which equilibrium exists, viz., those having simple and those having complex nutritional requirements. It is shown that soil extracts contain one or more growth factors, other than the vitamin B complex, essential for certain species. Other species produce in the substrate a growth factor necessary for the growth of some but not all of the organisms which need the factors present in soil extract. Evidence is accumulating that accessory factors may have a considerable influence on the species-distribution of soil organisms.

**References**

(1) *Soil. Sci.*, 1942, **58**, 93.
(2) *Comm. 3rd Internat. Cong. Microbiol.* Abs., 1939, 304.
(2A) *Soil. Sci.*, 1940, **50**, 295.
(3) H. Katznelson, *Soil. Sci.*, 1940, **49**, 283.
(4) *Canad. J. Res.*, 1942, **21**, C, 119.
(5) *Pedology*, 1939, No. 12, 46.
(6) *Soil Sci.*, 1940, **49**, 171.
(7) P. M. West and A. G. Lochhead, *ibid.*, **50**, 409.
(8) *Ibid.*, 1943, **55**, 185.

## TRANSMISSION OF INTERNAL BOLL DISEASE OF COTTON BY THE COTTON STAINER

Internal boll disease of cotton is caused by *Nematospora gossypii* Ashby and Nowell and allied fungi, and it has long been known that various plant bugs, especially cotton stainers of the genus *Dysdercus*, are responsible for the transmission of the disease. A recent paper* by Dr. Helen L. Frazer elucidates for the first time the actual method of transmission of the fungus by the insect vector. The following is taken from the author's summary:

"Results are presented to show that all the rules of proof for insect transmission of *Nematospora* by *Dysdercus* spp. have now been satisfied: viz. a close association of the insect with diseased plants in nature; visitation of healthy plants by the insect under conditions suitable for transmission of the disease; the presence of the pathogen in or on the insect in nature or following visitation to a diseased plant; and experimental production of the disease by insect visitation under controlled conditions. Hence it is claimed that *Dysdercus* spp. are proved vectors of internal boll disease of cotton.

Fungal material as spores or mycelium is carried as an external contaminant on the mouth-parts, although it is located in the deep stylet pouches, where protection is afforded and spore germination is possible. The fungus is cast off with the exuviae during moulting, but recontamination from exuviae or other sources in the environment occurs.

The transmission is hence purely mechanical with the insect obligatory only in its function as a syringe to inject the fungus which is otherwise unable to reach its substrate. Insect and fungus can develop independently and the insect is apparently unharmed by the presence of the fungus. *Nematospora* spores also reach the intestine but do not appear to remain viable there and do not germinate. The fungus is believed to enter and leave the insect by the same route. The spores are well adapted in shape to reach the stylet pouches of the insect. No alternative morphological form of *Nematospora gossypii* within the insect has been found.

The results do not lead to methods of control of the disease beyond those in practice—trapping of insects, destruction of alternative host plants, and the alteration of time of planting to avoid insect attack."

* "Observations on the method of transmission of internal boll disease of cotton by the cotton strainer-bug." *Ann. Appl. Biol.* **31**: 271-290.

# PEASANT FARMING IN THE BEJUCAL AREA OF TRINIDAD

BY

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(*The following article is a summary of results from an economic survey in the Bejucal area; a few typescript copies of the full report are available on loan from the Economics Department of the College.*)

## Introduction

The Bejucal (pronounced Bewakal) area is situated in the north-west of Trinidad about eight miles to the west of the Las Lomas district (1). The area forms the eastern boundary of the Caroni swamp and the western boundary of Caroni Sugar Estate (Figure 1). The area covered by the survey is about 5 square miles in extent. The soils are mostly heavy, stiff, highly acidic clays containing variable amounts of organic matter of a swamp or "lagoon" kind and are deficient in phosphates though fairly abundantly supplied with potash. They are very badly drained because of their low lying position and their compact impervious structure. Their lime requirements are high to very high ranging from about 10 to 21 tons ground limestone per acre (Figure 2).

The area was developed only comparatively recently. The sugar planters of the 19th century, whose properties were ultimately amalgamated into the present large sugar estates, did not take up land in Bejucal presumably because of the swampy and unhealthy nature of the area. For this reason Bejucal remained practically uncultivated until 1895 when parcels were for the first time allotted to East Indian labourers who wished to remain in the island on the completion of their indentured service. About seven-eights of the area was distributed to East Indians from 1895 to 1907; the usual grant consisted of about 3 acres. The population has remained purely East Indian, the bulk (about 80 per cent.) being Hindu by religion; there are, however, no observable differences in the farming of peasants of other religions.

The amenities of the area are on the whole good. The area is well roaded and includes a Government Railway Station at Cunupia at which the Department of Food Control maintains a buying point. Caroni estate has three cane weighing scales available for the area. Two primary schools serve the area although neither is within it. The chief deficiency is in respect of piped water which is only available a mile or more from most homesteads.

War conditions have affected Bejucal probably less detrimentally than any other area or population in Trinidad. Increased wages and employment have increased the wage earning capacity of the people, particularly as work at the United States Naval Base was available during the survey year. The high prices and shortages of goods (particularly foodstuffs) have been only a minor hardship to the people because their wants have always been simple and one-half of their food supply is home produced. Indeed, high prices and the big demand for local foodstuffs have benefited the peasant in making his provision crops more saleable than in peace time. It should therefore be remembered that the results published in this report cover a period of definite prosperity.

The object of the survey was to obtain a representative sample of the whole agricultural community in Bejucal. It is estimated that between two-and three-fifths of the population is represented by the sample of 168 holdings. Every effort has been made to obtain a complete picture of the activities of each family; all sources of income and, as far as practicable, all items of expenditure have been obtained; the total working time of the whole family has been apportioned between various occupations including that time available for field work on the holding; the time available for the holding has been allocated to various crops on an acreage basis weighed according to the crop grown; gifts and exchanges of land, manure and labour have also been taken into account.

## Occupation

The population in Bejucal, according to Trinidad standards is very dependent on agriculture. About half the total income was obtained from the cultivation of the holding and an additional one-fifth was obtained from agricultural employment off the holdings; thus, only thirty per cent. of the income was obtained from non-agricultural activities. About three-quarters of the agricultural work off the holding consisted of employment by other peasants. It is not surprising, therefore, to find that labour was by far the largest item of agricultural expenditure.

The degree of dependence of farmers on occupations away from their holdings varied widely in individual cases; some farmers were entirely whole-time on their holdings, in the sense that they derived the whole of their income from their holdings; others derived as little as 8 per cent. from their holding. The employment of labour by peasants was not therefore a system of exchanges; some peasants were regular employers of others. Farmers were part-time for a number of reasons: Some had insufficient land to occupy them full-time; the small holding which usually consisted of a large proportion of rice was particularly unsuited to full time farming because of the seasonal nature of labour requirements for rice. Others had too many persons in the household for all to be fully occupied; the most typical large household occurred when two or more families worked one holding; in these families one or two members could find profitable employment

(usually periodically) away from the holding. Still other families had accumulated surplus savings which they invested in land or some type of non-agricultural business.

Table 1 shows the variation in the dependence of these peasants on their holdings. It can be seen that the largest farmers were full-time and it appears that less than 6 cultivated acres were insufficient to make an appreciable contribution to the income required by the average peasant. It is striking that whole-time farmers were distinctly more prosperous than others. The Table shows also the substantial incomes that were earned throughout. The average income per holding was $1,250.

### Livestock

Crop production far outweighed livestock. The income from crops was five times as great as the income from livestock and livestock products. Large animals were kept mainly for draft purposes, breeding and production being side lines; small stock, chiefly goats and poultry, were kept mainly for household consumption. The average stocking per holding was about two cattle-units or rather less than half a unit per cultivated acre; the amount of farm yard manure used averaged 5 tons per holding or about 4½ tons per acre dressed

The net income from livestock amounted to $80 per holding. Other indirect benefits from livestock were difficult to show, but they appeared to be mainly that draft livestock increased the versatility of the farmer; both his versatility in the cropping of his holding and his versatility in occupying his time on and off the holding. There is no doubt that a carter or a ploughman was in demand most months of the year and good earnings could be obtained from these occupations. The small farmer, however, could not avail himself of these advantages because he had difficulty in accumulating sufficient savings to equip his holding with draft animals and equipment (estimated at $360) and because the responsibility of large animals restricted his scope in seeking wage employment.

### Cropping

Farmers practised almost universally a system of three crop farming; cane, rice and provisions (almost entirely eddoes, *Colocasia* ssp.) were the three major crops; so called "fine gardens", a miscellaneous mixture of vegetable crop, were also grown but only on 2 per cent. of the acreage; this crop usually did not represnt commercial vegetable cultivation. Sixty per cent. of the peasants, cultivating 84 per cent. of the land, operated three crop farms; 13 per cent. of the land consisted of two crop farms and only 3 per cent. of one crop farms. There were no large one crop farms; but three crop farms ranged from 1 to 35 cultivated acres. It can be seen from Table 1 that the average size of holding was about 5½ cultivated acres.

No rotation was practised between the three crops and, indeed, there was little opportunity for such a practice. The absence of rotation can be shown by the average length of time the present crops had been cultivated on individual lots of land. Farmers on the average had cultivated some land for the past 13 years; they had cultivated present cane lots continuously in cane for the past 10 years, rice for 9 and provisions 6 years. The comparative youth of provision lots was caused by cane land being broken up in order to take advantage of the recent good market for local foodstuffs; the two crops are inter-changeable and interchange does evidently take place according to relative prices and other conditions. This kind of interchange, however, can hardly be regarded as a system of rotation. Rice lands on the other hand are unsuitable for cane and provisions and no interchange or rotation is possible; a dry season crop of "urdi" (Woolly Pyrol, *Phaseolus mungo*) was grown on one-quarter of the rice lands.

The main advantage of three crop farming to these peasants was in the distribution of labour throughout the year; the advantage of obtaining cash at six monthly instead of yearly intervals can be considered as only a subsidiary advantage since the small farmer in any case relies on wage employment to a large extent; the large farmer has usually ample financial reserves to carry him

**Table 1**

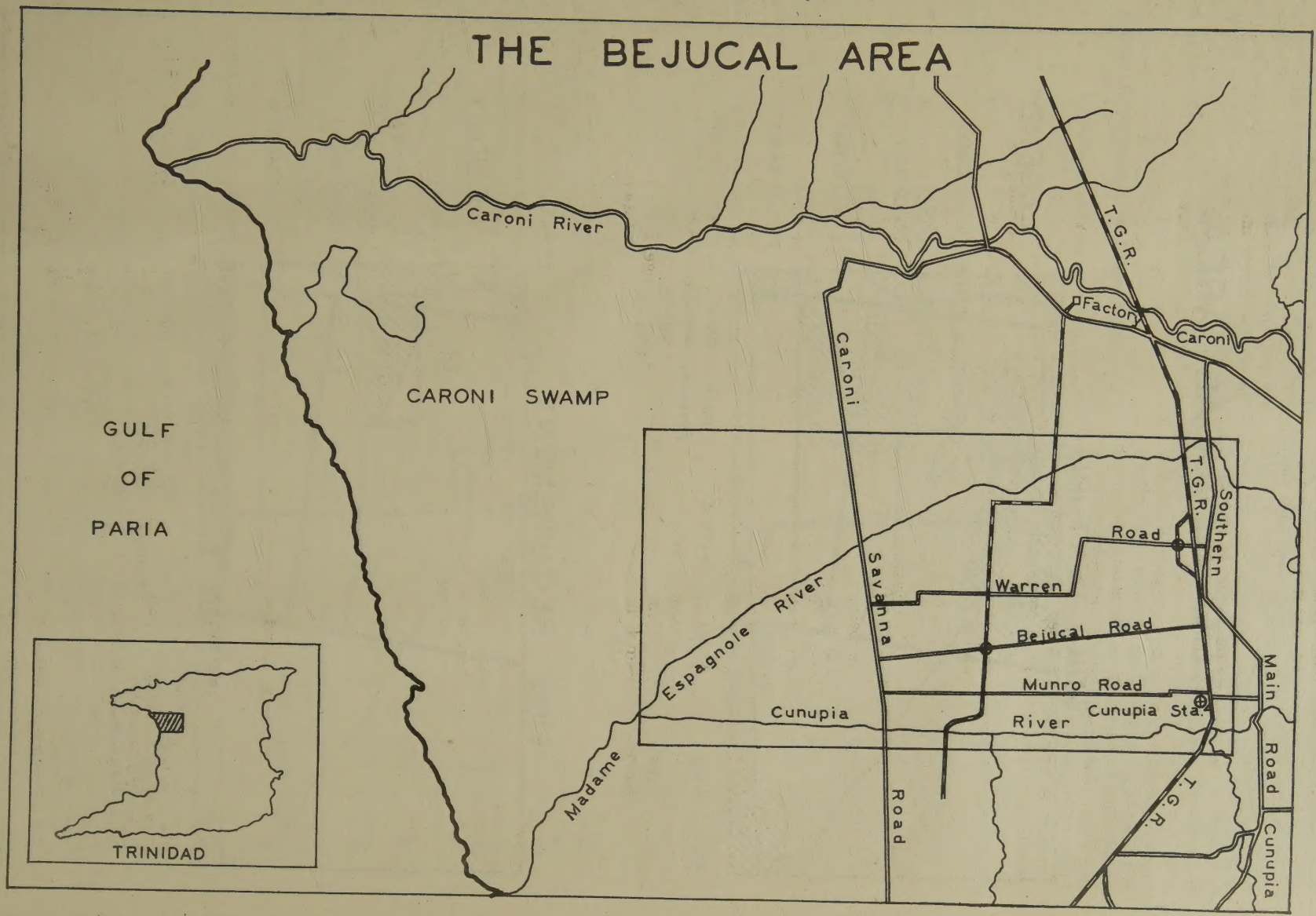
**Holdings Classified according to Percentage of Total Income Derived from Holding**

| % of Income from Holding | 0-19 | 20-39 | 40-59 | 60-79 | 80-100 | All |
|---|---|---|---|---|---|---|
| Number of Holdings ... ... | 12 | 41 | 65 | 34 | 16 | 168 |
| Cultivated acreage ... ... | 14 | 115 | 392 | 218 | 199 | 938 |
| Cultivated acreage per Holding ... | 1.19 | 2.78 | 6.03 | 6.36 | 12.45 | 5.59 |
| Crop Income per cultivated acre ... | $67 | $98 | $100 | $108 | $116 | $100 |
| Total Income per Consumer Equivalent | $209 | $258 | $308 | $277 | $421 | $293 |
| Total Income per Man-day* ... | $1.00 | $1.22 | $1.44 | $1.41 | $2.10 | $1.42 |

* Man-days in this case include the time of all potential workers (*e.g.* the housewife's time, although it may have been devoted entirely to housework, was included). $1 Trinidad—4/2 (50d.)

# FIGURE I

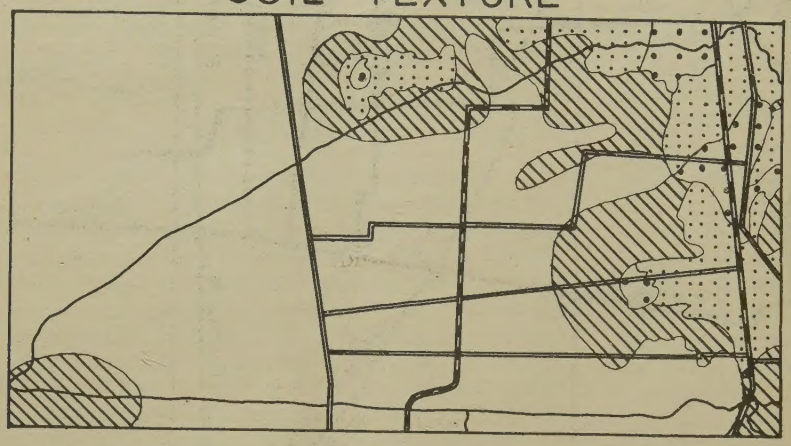
## THE BEJUCAL AREA



# FIGURE 2

## THE BEJUCAL AREA

### SOIL TEXTURE

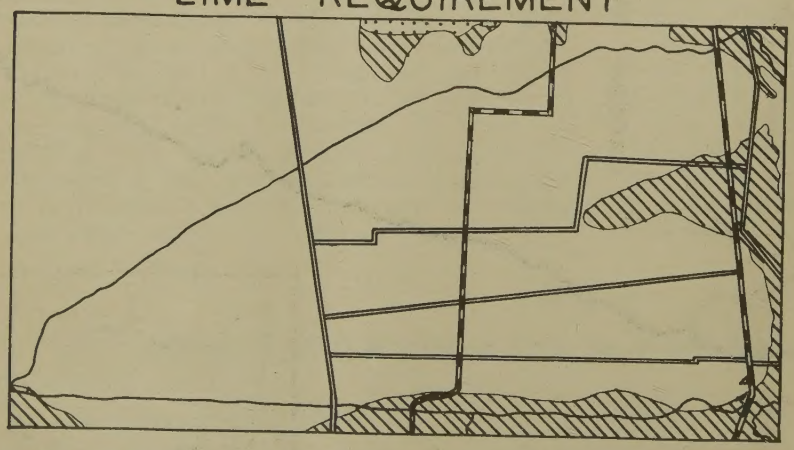


LEGEND

- CLAY
- SILT
- LOAM
- SAND

| | | | |
|---|---|---|---|
| Note : | Clay | Index of Texture | Above 50 |
| | Silt | | Between 49-40 |
| | Loam | | 39-25 |
| | Sand | | 24-0 |

### LIME REQUIREMENT



LEGEND

- V. High
- High
- Medium

| | | |
|---|---|---|
| Note : | V. High | Over 20 tons/acre |
| | High | Between 19-10 |
| | Medium | 9-5 |

through the year. Table 2 gives details of labour requirements for the three crops; the dates are of course approximate since they will vary from one year to another. It can be seen that no crop has balanced requirements; but a combination of the three keeps the farmer well occupied throughout the year; indeed, it is difficult to choose a time in Bejucal when work of some kind is not in hand.

**Table 2**

**Labour Requirements of Three Crops**

| | Ratoon Cane* | Rice | Provisions |
|---|---|---|---|
| Approximate dates for: | | | |
| Preliminary cultivation ... | — | Aug.-Sept‖ | June-July |
| Planting ... | — | Aug.-Sept. | July |
| Cultivation ... | May-Dec. | —† | July-Oct. |
| Harvesting ... | Jan.-May | December | October‡ |
| Relative Total Labour Requirements | 1 | 3 | 2 |
| Remarks ... | Much latitude in time and amount of labour required | Most exacting as regards time. Heavy requirements. | Requirements spread fairly evenly over whole period of cultivation |

* Plant-cane has been excluded because only 18 farmers (11 per cent. of the total) planted any.

† A weeding may be done, usually Sept.-Oct., according to the cleanness of the crop.

‡ Provisions are sometimes left in the ground until January.

‖ Some clearing and ploughing is done in July, but farmers with provisions do not usually plough for rice until the beginning of August.

Cane was primarily a large farmer's crop (Table 3). Rice, although grown more commonly than any other crop, was rarely cultivated on a large scale; only 7 farmers with 18 per cent. of the total rice acreage cultivated 5 or more acres each. A small variation in acreage per holding was indeed very characteristic of rice, more than half the total acreage being grown at between 1 and 3 acres per holding. Provisions, partly because of the good market, were well suited to holdings of all sizes; (note the comparative uniformity of the percentages for Provisions in Table 3).

Table 4 gives a comparison of costs and income for the three major crops. It is evident that high income per acre and per man-day was earned from provisions in spite of high costs being incurred. Rice was the second most costly crop but yielded relatively low net income. Cane was an extensive crop, low costs and low income per acre being characteristic; it is to be noted, however, that the earnings per man-day were considerably higher for cane than for rice.

The range in net income of the three crops is compared in Table 5. It can be seen that rice and provisions gave very variable results, provisions rather more so than rice. The income from cane, on the other hand, showed comparatively little variation, nearly two-thirds of the acreage being cultivated at a profit of $0-50 per acre. Cane was therefore the safest crop; provisions offered the

**Table 4**

**Income and Costs per Acre for Three Crops**

| Acreage | Cane | Rice | Provisions |
|---|---|---|---|
| | 438 | 251 | 225 |
| ($ per Acre) | | | |
| Income ... ... | 60 | 94 | 174 |
| Total Labour (ex family labour) ... | 15 | 39 | 25 |
| Manure ... ... | 2 | — | 3 |
| Rent* ... ... | 3 | 5 | 4 |
| Seed ... ... | — | 4 | 28 |
| Total Cost ... ... | 20 | 48 | 60 |
| Net Income ... ... | 40 | 46 | 114 |
| Family Man-days available per acre .... | 35 | 63 | 65 |
| Net Income per Man-day available ... | $1.14 | $0.72 | $1.75 |

* Land rented for $8-$10 per acre but all land was not, of course, rented: 40%, 47% and 43% respectively of the Cane, Rice and Provision land was rented.

**Table 3**

**Average Acreages according to Size of Holding**

| Cultivated acreage of Holding | Less than 2 acres | | 2.0-3.99 | | 4.0-6.99 | | 7.0 Acres & over | | All | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | % | Acres | % | Acres | % | Acres | % | Acres | % |
| Cane ... ... ... ... | 0.2 | 18 | 0.8 | 29 | 2.2 | 43 | 7.5 | 57 | 2.6 | 47 |
| Rice ... ... ... ... | 0.7 | 53 | 1.0 | 35 | 1.3 | 25 | 2.9 | 22 | 1.5 | 27 |
| Provisions ... ... ... | 0.3 | 25 | 0.9 | 31 | 1.4 | 28 | 2.7 | 20 | 1.3 | 24 |
| Fine Gardens ... ... ... | — | 4 | 0.1 | 5 | 0.2 | 4 | 0.1 | 1 | 0.2 | 2 |
| Total ... ... ... ... | 1.2 | 100 | 2.8 | 100 | 5.1 | 100 | 13.2 | 100 | 5.6 | 100 |

**Table 5**

**Profitability of Three Crops per Acre**

| | Cane | | Rice | | Provisions | |
|---|---|---|---|---|---|---|
| | Acres | % | Acres | % | Acres | % |
| *Losses* | | | | | | |
| -$47-$25 | 8 | 2 | 1 | — | — | — |
| -$24-$0 | 9 | 2 | 19 | 8 | 3 | 1 |
| *Profits* | | | | | | |
| $0-$24 ... | 161 | 37 | 50 | 20 | 6 | 3 |
| $25-$49 ... | 97 | 22 | 74 | 29 | 18 | 8 |
| $50-$74 ... | 99 | 23 | 55 | 22 | 29 | 13 |
| $75-$99 ... | 37 | 8 | 32 | 13 | 44 | 20 |
| $100-$124 ... | 15 | 3 | 18 | 7 | 42 | 19 |
| $125-$149 ... | 11 | 3 | 2 | 1 | 35 | 15 |
| $150 and Over | 1 | — | — | — | 48 | 21 |
| Total ... | 438 | 100 | 251 | 100 | 225 | 100 |

possibility of very high profits but entailed considerable uncertainty ; rice offered almost equal uncertainty and no prospect of high profit.

### Cane Cultivation

The net income from cane per acre was somewhat less variable than indicated in Table 5 which includes 35 acres of plant-cane. Plant-cane results varied according to whether planting costs fell within the survey year and to whether the first crop was reaped during the year. Planting costs (apart from an average of 20 family man-days available) averaged $60 per acre ; the crops that were reaped averaged 20 tons per acre or twice as much as the average of ratoons.

It is surprising therefore to observe that the relatively small variation in net income from ratoon cane was obtained from very variable yield ; ratoon yields ranged from 2 tons to more than 20 tons and the gross income from $5-$125 per acre. Table 6 shows that high yield and high gross income was obtained at high cost so that the net income varied considerably less than the gross income. About half (56 per cent.) of the hired labour for ratoon was for harvesting which varies directly with the crop obtained. Cane is, therefore, a crop that is extremely flexible as to total labour requirements ; at present prices ($5.50 per ton) high cultivation results in good returns ; neglect, on the other hand, does not often result in a loss.

Table 6 shows that the advantages of high cultivation were generally ignored and that half the acreage was cultivated at a low standard. This neglect was attributable to the temporary condition of high profit from provision cultivation which diverted labour from cane cultivation to provisions ; the diversion was particularly in respect of replanting cane. During the survey year only 35 acres were replanted (a rate of once in 13 years) whereas the average age of standing cane was 4 years old. An analysis of age of cane fields showed that very little (12 per cent.) cane over 3rd ratoon yielded more than 7 tons per acre.

**Table 6**

**Ratoon Cane Results Analysed according to Yield per Acre**

| Yield per acre | Under 7 tons | 7.0-10.9 | 11.0-14.9 | 15.0-18.9 | 19 tons & over | All |
|---|---|---|---|---|---|---|
| Acreage | 126 | 128 | 51 | 67 | 31 | 403 |
| ($per acre) | | | | | | |
| Income | 23 | 48 | 72 | 98 | 129 | 58 |
| Labour | 4 | 11 | 16 | 18 | 33 | 12 |
| Manure | — | 2 | 2 | 2 | 3 | 1 |
| Total Cost | 7 | 18 | 20 | 22 | 41 | 17 |
| Net Income | 16 | 30 | 52 | 76 | 88 | 41 |
| Man-days available | 29 | 45 | 40 | 40 | 32 | 38 |
| Net Income per Man-day | $0.55 | $0.67 | $1.30 | $1.90 | $2.76 | $1.08 |

These observations on cane cultivation apply to a period of labour shortage ; should wage employment and the demand for provisions decrease, cane cultivation will provide a profitable method of employing surplus labour. More intensive cane cultivation would give increased work at crop (harvest) time and, with more frequent replanting, also at other times of the year.

### Rice Cultivation

The relationship between profits and yields for rice were found to be the reverse of that for cane. With rice, profits were variable but yield was remarkably constant. Although rice is agriculturally the most difficult of the three crops, two-thirds of the acreage yielded between 2,000 and 3,000 lbs. paddy per acre. This small variation is undoubtedly due to the peasants' anxiety to avoid a crop failure : no complete failures were recorded and only one-fifth of the acreage yielded less than 1,500 lbs. per acre.

A more detailed analysis of the profitability of rice is given in Table 7 ; it can be seen that labour cost was a very variable item and accounted to a large extent for the variation in net income. The cost of hired labour evidently had little connection with yield and gross income, and it appears therefore that labour was often wastefully applied. Wasteful employment of hired labour is more clearly shown in Table 8 ; even when family labour was super-abundant, hired labour was employed at the rate of $37 per acre.

It appears, therefore, that rice was not generally cultivated on commercial lines ; the first concern of the average farmer with one or two acres of rice

FIGURE 3

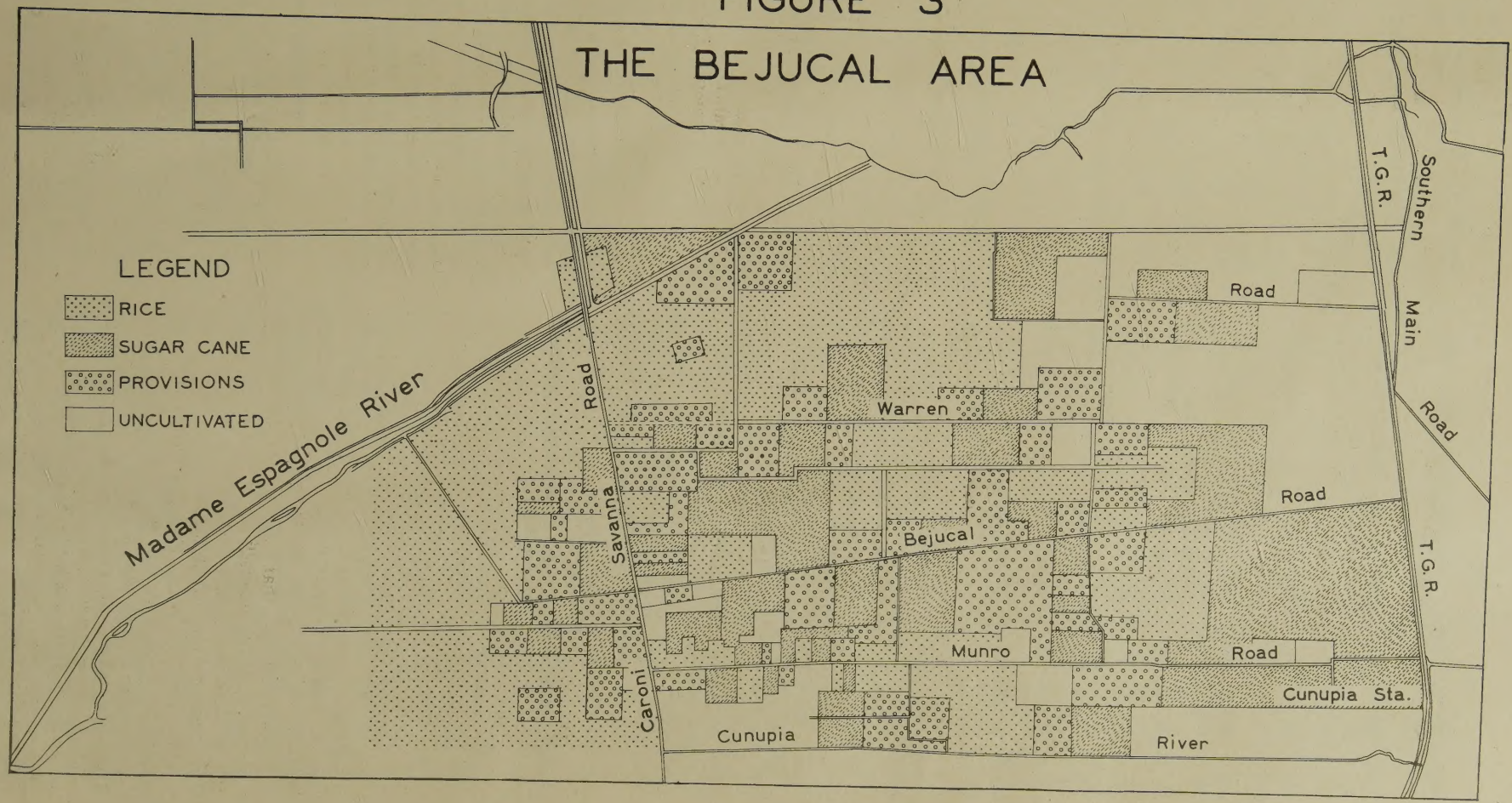

THE BEJUCAL AREA
LEGEND
RICE
SUGAR CANE
PROVISIONS
UNCULTIVATED
Madame Espagnole River
Savanna Road
Caroni
Cunupia
Warren
Bejucal
Munro
Road
Road
Road
Road
Cunupia Sta.
River
T.G.R.
Southern Main Road
T.G.R.

**Table 7**

**Rice results, Analysed according to Net Income per Acre**

| Net income per acre | losses | $0-49 | $50-99 | $100-149 | All |
|---|---|---|---|---|---|
| Acreage ... | 20 | 124 | 87 | 20 | 251 |
| ($per acre) | | | | | |
| Income ... | 63 | 81 | 108 | 141 | 94 |
| Labour ... | 61 | 44 | 31 | 22 | 39 |
| Total Cost | 72 | 54 | 38 | 27 | 48 |
| Net Income | (–)9 | 27 | 70 | 114 | 46 |
| Man-days available | 50 | 62 | 63 | 85 | 63 |
| Net income per Man-day | (–)$0.18 | $0.44 | $1.11 | $1.34 | $0.72 |

**Table 8**

**Family and Hired Labour on Rice Cultivation**

| Family Man-days available per acre | 1-29 | 30-39 | 40-49 | 50-59 | 60 & over | All |
|---|---|---|---|---|---|---|
| Hired labour cost per acre $ | 42 | 37 | 38 | 40 | 37 | 39 |

was to ensure a successful crop. If he had funds to employ labour he would do so, whatever his family labour supply, in order to ensure that the cultural operations were carried out within a period of good conditions. The peasant's concern over his rice crop is understandable when it is realised that 70 per cent. of the crop is consumed in households and that this food (valued at 3½c. per lb. paddy) makes up one-quarter of the total food expenditure. These facts explain why peasants willingly continue rice cultivation for a relatively low return of only 72 cents per man-day available. It may be noted that work on rice is usually harder than on the other two crops.

### Provision Cultivation

The yield and gross income for eddoes was very variable; the gross income was fairly evenly spread over a range of $120 to $250 per acre and yields from 2,000 to 7,000 lbs. per acre. Costs bore little relation to yields and income as shown in Table 9. It is obvious, therefore, that relatively unproductive expenditure was incurred on many provision cultivations. This waste arose from causes different from those of rice. Provisions, of the three, was at the time of the survey the pre-eminently commercial crop and there is no doubt that farmers made every effort to obtain a *profitable*

**Table 9**

**Provision Results, Analysed according to Gross Income per Acre**

| Gross Income per acre | Under $100 | $100-$199 | $200-$299 | $300 & over | All |
|---|---|---|---|---|---|
| Acreage ... | 17 | 141 | 54 | 13 | 225 |
| ($ per acre) | | | | | |
| Income ... | 72 | 151 | 228 | 336 | 174 |
| Labour (ex family) | 8 | 25 | 31 | 28 | 25 |
| Manure ... | 1 | 2 | 4 | 6 | 3 |
| Rent ... | 4 | 4 | 4 | 4 | 4 |
| Seed ... | 21 | 28 | 28 | 28 | 28 |
| Total Cost ... | 34 | 59 | 67 | 66 | 60 |
| Net Income ... | 38 | 92 | 161 | 270 | 114 |
| Man-days available | 54 | 59 | 75 | 94 | 65 |
| Net Income per Man-day available | $0.66 | $1.56 | $2.15 | $2.87 | $1.75 |

crop. The crop, however, entails heavy expenditure which does not always result in high yield and income; seed cost, for instance, was a far heavier item per acre and as a proportion of costs (46 per cent. of the total) than for rice (only 8 per cent. of the costs). It can be seen from Table 10 that labour costs for provisions consisted to a far larger extent of pre-harvesting costs than for the other two crops.

The variability of the final provision crop, therefore, makes the expenditure something of a gamble and explains why large farmers with ample cane land to convert did not risk more than 20 per cent. of the holding under provisions.

**Table 10**

**Details of Labour Costs (where available) per Acre for Three Crops**

| | Ratoon cane | | Rice | | Provisions | |
|---|---|---|---|---|---|---|
| Acreage with labour | 171 | | 118 | | 62 | |
| Costs per Acre : ... | $ | % | $ | % | $ | % |
| Preliminary Cultivation | 3 | 15 | 11 | 30 | 13 | 45 |
| Planting ... ... | 1 | 6 | 7 | 19 | 8 | 26 |
| Cultivation ... | 6 | 33 | 1 | 3 | 5 | 16 |
| Harvesting ... | 9 | 46 | 18 | 48 | 4 | 13 |
| Total ... ... | 19 | 100 | 37 | 100 | 30 | 100 |

### Conclusions

The most interesting findings of the survey are the economic characteristics of the three main crops as grown by the peasants. Cane is the safe low profit crop, well suited to the large "proprietor" farmer and capable of profit earning at very varying standards of cultivation. Rice is the non-commercial crop, wide variations in profitability

being attributable mainly to wasteful employment of labour. Provisions is the high profit crop but involves heavy cultural expenditure before the very variable crop is reaped. Of the three, provisions is the biggest gamble.

*Rice.* In drawing conclusions and making recommendations, these characteristics must be taken into account. For instance, there are several ways of cheapening the cost of rice cultivation, but the character of the crop is such that the peasant evidently has little interest in low cost production. Part of the wasteful expenditure on rice cultivation is due to his anxiety to obtain an ample food supply from his acre or so of the crop and part is no doubt due to his inheren liking for, and pride in, the crop that figures so largely in his daily meals. Indeed, rice growing appears to be much more a part of the peasants' family life than of his business activities as a farmer.

The character of the rice crop as shown by the survey raises the whole question of whether it is feasible in Trinidad to obtain an appreciable surplus of rice at reasonable prices from peasant production. Under present methods of cultivation rice would have to sell at very high prices (at least 7 cents per lb. paddy off the holding) for peasants to obtain earnings comparable with other crops. On the other hand, cheapening of costs could only be achieved by destroying the essentially " family " nature of the crop. Costs could be cheapened by co-operative cultivation of areas considerably larger than the one or two acres of the individual peasant, but such co-operation would destroy the peasant's independence as a provider for himself and his family.

The recommendation to be made about rice is therefore that if the policy is to obtain a supply for urban consumption at reasonable prices, production from estates rather than from peasants appears more likely to attain the object. If the more important object is to develop a contented and self reliant peasantry, the policy most likely to succeed with East Indians is that of making rice lands available to them.

*Cane.* The general low standard of cultivation of cane was attributable to sound commercial reasons. So long as wages are high and earnings from provision cultivation remain good, cane will be relatively neglected. The degree of neglect could, however, be reduced even under present conditions by the improvement in harvesting arrangements. The inefficiency of harvesting and transport have been examined in a previous report on Las Lomas (1) and apply almost equally to Bejucal; farmers have little incentive to grow large crops of cane when they know that time wasted at the weighing scale may delay the preparation of other lands for the profitable provision crop. It is suggested that co-operative harvesting of canes is the most essential step to the improvement of harvesting efficiency. The reason why no voluntary co-operation has developed is presumably because the leaders of the area are themselves large cane farmers; they obtain preferential treatment at the scale and they can pay the many carters they employ by the load rather than the day; they therefore do not suffer directly from the time wastage.

*Provisions.* It appears that an agricultural investigation of the provision crop in Bejucal is desirable. The survey shows very variable yield and income in spite of consistently heavy expenditure. A further investigation of provision lots would be necessary to determine what factors cause these variations.

Nevertheless, the costs of provision cultivation appear in any case unduly high and are attributable to the fact that all operations (except the preliminary ploughing) are performed by hand. The performance of all operations by hand should be unnecessary since most of the provision lots are over one acre in extent. It would appear that a light double breasted plough would be a most useful implement for the crop and would lessen the cost of planting and moulding. Much of the provision crop was sold in the ground to traffickers because of insufficient labour for digging the tubers. It is suggested that an animal drawn implement working on the principle of a sugar beet lifter would enable farmers to cope with harvesting themselves.

*General.* The survey has been of particular interest to officers participating in it because of the close-up picture it has given of the East Indian farmer; of the farmer both as a businessman and as a person. It is most striking that the farmers are industrious and keen agriculturists; their ambition often lead them to engage in business other than agriculture; but even then their interests appear still to be centred on the land. On the whole, they are but little prejudiced and listen with interest to suggestions for, and descriptions of, improvements; whether they adopt such suggestions is usually determined by sound commercial considerations.

A striking feature of their farm organisation is the way in which two second generation families operate the farm they have inherited jointly (plus usually a considerable added acreage). The two families may live in the same or adjoining houses and appear to work together quite amicably. The two-family farm is a much stronger economic unit than if it were split between the families. The arrangement is good, not only because it avoids fragmentation, but also because the two-man holding is in a much sounder position as to family labour. Many operations require two men, and others as large a labour force of both women and men for a short period of time. This system has led to considerable prosperity and with extra land many of these farmers are at present large employers of labour.

**Reference**

(1) Parisinos, C. C., Shephard, C. Y. and Jolly, A. L. Peasant Agriculture. *Trop. Agriculture*, Vol. XXI, No. 5.

# PLANT VIRUSES AND VIRUS DISEASES *

BY

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The existence of viruses was first deduced from work done in 1892 on tobacco plants suffering from mosaic, and much of what we now know of these elusive entities has come from further work on this and a few other plant diseases. It is far from certain that this knowledge can safely be applied to the causes of the many diseases, affecting all kinds of animals, higher plants and bacteria, that are now attributed to viruses. These cover a wide range of clinical conditions, and we know for certain of only two features that they have in common ; their causes have neither been seen nor cultivated *in vitro*. If we wish, we can turn these negative features into what looks like a positive statement, by defining viruses as obligately parasitic pathogens too small to be resolved by microscopes using visible light. Indefinite as this is, it may still prove to be more precise than the facts warrant, for obligate parasitism is always postulated rather than proved, and serious attempts at cultivation have actually been made with very few viruses. Thus, when we speak of a virus disease, we usually mean merely an infectious disease with an invisible cause. Unless the resolving power of the microscope has some unsuspected significance in defining biological types, this obviously tells us nothing specific about the nature of viruses and might well cover a range of different entities.

This possibility seems increasingly likely when we try to generalize about plant virus diseases, for we find that no statements can be made about such features as symptoms, methods of infection, or distribution of virus in the host, to which there are no exceptions. This is far from conclusive, however, for what a virus does to a plant is as much a property of the plant as of the virus, and the same virus may produce very different effects in different plants. Also, although complete generalizations are impossible, there are some features shared by a number of different virus diseases, especially those met commonly in Nature.

The effects most frequently caused by viruses are a dwarfing of the host plants and an alteration of the colour and shape of the leaves. Instead of being uniformly dark green, the leaves may bear spots, rings or patches of light green, yellow or white, or they may be generally chlorotic without definite mottling. Deformation may show only as an alteration in the leaf outline, or the laminae may be so reduced that the leaves consist of little but the main veins ; it may take the form of local hyperplasia, to give unusual outgrowths from the leaves or gall-like proliferations in stems. Symptoms tend to occur more generally over a whole plant than with most fungal or bacterial diseases, for in natural infections it is usual for viruses to spread through the vegetative parts of affected plants. In plants infected experimentally, however, symptoms are often restricted to local lesions, produced by the death of tissues around the entry point. Diagnosis from symptoms is by no means easy, for different viruses may cause almost identical symptoms in the same host, whereas the same virus may produce totally different clinical conditions in different hosts. A further complication is that many viruses are unstable and frequently change to give forms that produce different symptoms from those produced by the parent virus. To be recognized, a virus must cause changes in the appearance of some plants ; but it need not necessarily cause changes in all susceptible hosts. Indeed, the phenomenon of the carrier—an infected individual showing no symptoms—is common in plants, and such carriers can be of considerable importance as unsuspected sources of infection for intolerant species.

In many virus diseases, three distinct phases can be identified. As a result of virus multiplication at sites of infection, lesions first appear on inoculated leaves. After a few days, the virus passes to the phloem, through which it travels rapidly to distant parts of the plant. It seems to have no autonomous movement, but to travel along with the translocation stream of elaborated food materials, away from tissues actively engaged in photosynthesis and towards regions of active growth. It is because of this, and not because they resist infection, that leaves already fully developed at the time the plant becomes infected rarely show symptoms. Thus results of systemic infection appear on the young, actively growing leaves; the later symptoms of this systemic phase often differ from those first produced, as the disease passes from an acute to a chronic stage. Often both stages are serious diseases ; in many potato varieties, for example, leaf drop-streak is succeeded by severe mosaic. Occasionally, however, the chronic stage is extremely mild, such as in tobacco plants with ring-spot, which recover from an acute necrotic disease and afterwards show few or no symptoms. The virus is present in such plants, but in smaller quantities than during the acute stage. The sequence of three phases is common, but by no means general, and the same virus may give different sequences in different hosts. Potato virus Y, for example, gives local lesions only in one host, local lesions followed by systemic symptoms of two kinds in a second host, whereas in a third it gives no local lesions and systemic symptoms of only one kind.

In addition to altering the external appearance of plants, viruses also produce internal changes. Some of these are simply modifications of normal

* Substance of two lectures delivered at the Royal Institution, reproduced from *Nature*, Vol. 155, No. 3928, 1945.

structures of tissues, such as reduction of the chloroplasts or necrosis of the phloem ; but the most characteristic involve the production of new kinds of intracellular inclusion bodies. These are not found in all virus diseases, but their formation appears to be specific to viruses, for similar bodies have not been found either in healthy plants or in those suffering from other kinds of disease. Different viruses give rise to different kinds of inclusion body, and produce them in varying numbers and in different tissues. The most general type is a vacuolar, amoeboid-like body found in the cytoplasm, but crystalline and fibrous inclusions also occur in infections with a number of different viruses. At least two viruses give rise to crystalline inclusions in the nuclei. The precise nature of these bodies is still uncertain ; but we know that they contain virus, and their production can in part be simulated *in vitro*. It seems most likely that they are insoluble complexes produced by the viruses combining with some metabolic product of the diseased plants.

Symptomatology without proof of transmissibility is sufficient to assign a particular disease to the virus group, for similar kinds of symptoms can be caused by toxins, deficiencies of mineral nutrients and aberrant genes. With hosts that are easily grafted, transmission by grafting is usually the first method tried ; for once organic union is established, all viruses that cause systemic symptoms readily pass from infected scions into healthy stocks. Indeed, grafting is the only method of transmission known for many virus diseases, and it has almost become the critical test of a plant virus disease.

Infection occurs only through wounds, but wounds that permit one virus to enter may not permit another. Many viruses are readily transmitted by rubbing healthy leaves with sap from diseased plants, but others are not ; some of both these types are transmitted by insects. Several different explanations can be offered for the failure of inoculation to transmit viruses that are readily transmitted by insects. First, some viruses may be able to establish themselves only in deep-seated tissues, such as the pholem, which are not penetrated by ordinary inoculation methods. Secondly, conditions in the expressed sap of some hosts may be such that the viruses are rapidly destroyed or rendered non-infective. Thirdly, the virus content of sap from some diseased plants may be below that required for infection. Thus, although failure to transmit by inoculation is often used as a specific character of a virus, clearly it may equally well be a reflexion of some property of the host.

Insects do not seem to act simply as mechanical carriers of viruses, for no insect vectors are known for the two viruses most easily transmitted by inoculation ; and there appear to be specific relationships between insects and the viruses they transmit. Individual viruses are usually transmitted by only a few related species of insect and not by others, though these may have similar feeding habits and be vectors of other viruses. Vectors are usually insects with sucking mouth-parts ; the most important are aphides, leaf-hoppers, white-fly and thrips. Two main types of behaviour in the insect have been distinguished. Vectors of one type of virus can infect healthy plants immediately after feeding for a short time on a diseased plant, and these usually cease to be infective within a few hours. After feeding on diseased plants, vectors of the other type cannot infect healthy plants for some time, which varies from minutes to days with different viruses, and such vectors remain infective for long periods, often for their whole lives. Some workers believe that viruses of the second type multiply in the insects. There is no obvious reason why they should not, and the theory would explain some of the now puzzling features of the behaviour of these viruses ; but there is no conclusive evidence that insects ever contain more virus then they acquire while feeding on infected plants. Studies on the virus causing dwarf disease of rice supplies the best circumstantial evidence for multiplication. This virus is unique in being the only one known to pass from infective adults through eggs to their progeny. Progeny up to the seventh generation have once been found to be infective and from one infected egg the progeny have infected more than 1,000 plants. This is regarded by some workers as 'overwhelming' evidence for multiplication, as they consider that the quantity of virus in the original eggs could not have been enough to give all the infections. But is this so ? If the virus multiplied in the insects to anything like the extent it does in plants, then there would be no reason why the progeny should not continue to be infective indefinitely, and infect as many plants as they feed on. We know nothing of the size of this virus, but if it is of the same order as other plant viruses the sizes of which are approximately known, then 1,000 particles would weigh less than $10^{-14}$ gm., and many times this quantity could surely be contained in a leaf-hopper's egg without difficulty.

Transmission of some viruses has been achieved by linking diseased and healthy plants with the parasite dodder (*Cuscuta* sp.). This novel method of transmission promises to be valuable in extending the host ranges of some viruses to plants more favourable for study than those in which the viruses occur naturally. One of the greatest differences between individual viruses lies in the numbers of different plants they can attack. Some are known to infect hundreds of plant species, belonging to many different families and orders ; others have been transmitted to only a few closely related species. This difference may be apparent rather than real, for viruses transmissible only by grafting or by insects will normally have host ranges restricted to plants which can be inter-grafted or which can act as food plants for the insect vector.

For more than forty years, work on plant viruses was largely concerned with symptoms, transmission and host ranges. It showed that viruses could multiply and alter, and produced few results conflicting with the generally accepted conclusion that they were small organisms, essentially similar to bacteria. There were opposers

of this, usually from among those studying tobacco mosaic virus, but they could offer nothing definite to support their alternative views. The intensive study during the last ten years of the viruses *in vitro* has led to results that necessitate considerable modification of the earlier views. They do not, however, justify the sweeping conclusions implied by such facile phrases as 'lifeless molecules', which are increasingly applied to viruses.

What has been achieved is the successful application of the techniques of protein chemistry to the purification of a dozen or so viruses. This has shown us that the particles of these viruses are not organized cellularly like organisms, and that in many ways they resemble constituent parts of organisms rather than whole organisms. They can be obtained in forms chemically much simpler than bacteria, free from diffusible components, and with a much greater regularity of internal structure than is usual with organisms. The viruses so far purified have all been obtained in the same chemical form, as nucleoproteins. They all contain nucleic acid of the ribose type, but the proportion of nucleic acid to protein varies with the individual viruses. It is far too early to conclude that all plant viruses are essentially nucleoproteins; but we can say that it will be a major discovery if one is found to be anything else, for those already purified cover a diversity of types, some known to be insect-transmitted and others not. They range from potato virus Y, which denatures and loses infectivity within a few days, to tobacco mosaic virus, which remains stable for years. Stability as a native protein, however, is not always the same thing as stability as a virus; the infectivity of preparations of any of these viruses can be destroyed by some treatments that have no appreciable effects on the physical, chemical and serological properties.

The shape of the particle is responsible for some of the most striking differences between the properties of preparations of different viruses. Solutions of purified tobacco mosaic virus, and of potato viruses X and Y, show phenomena characteristic of greatly elongated particles; they are anomalous in all their physical properties and are polydisperse. No true crystals have been prepared from these, but dilute solutions show anisotropy of flow strongly, and concentrated solutions are liquid crystalline. X-ray studies of solutions of tobacco mosaic virus have demonstrated a regularity of structure previously unsuspected in fluids, for the particles are arranged equidistant from one another so that the available space is filled uniformly. When mixed with their antisera, these rod-shaped virus particles precipitate almost immediately, giving bulky, fluffy precipitates resembling those produced by bacterial flagellar antigens.

Solutions of bushy stunt and tobacco necrosis viruses behave very differently and show none of the anomalous properties characteristic of elongated particles. By suitable treatments they can be induced to crystallize in forms characteristic of the individual virus. When mixed with their antisera, they precipitate more slowly than the rod-shaped virus, and as might be expected with spherical particles, pack more closely to give dense, granular precipitates resembling those produced by somatic antigens.

What is the relationship between these isolated nucleoproteins, which in laboratory work behave much like preparations of other proteins, and the viruses as they occur, in the plant? There is enough evidence now to show that these proteins are the viruses in the sense that they can initiate infection. Nevertheless, it would be premature to assume that, while active in the host plant, the viruses are chemically so simple as analysis of the purified preparations suggests. During the course of isolation, many materials are discarded as impurities; most of these are certainly constituents of the normal host, but some may well be specific products of virus activity. Any such are clearly not essential for infectivity; but if the virus were organized cellularly, they would be retained within a cell wall and would be accepted as integral parts of the virus, which would immediately look a much more complex body than does our naked protein particle.

In the absence of specific tests for any product of virus activity, we have no positive evidence for their occurrence in plants, but evidence from various sources suggests that purification may be altering the viruses. Purified preparations of tobacco mosaic virus, for example, contain particles about 15 m$\mu$ wide but varying in length from less than 100 m$\mu$ to more than 1,000 m$\mu$. There is nothing to show that the greatly elongated particles occur in the plant, and much to suggest that they are produced by the linear aggregation of small particles during the course of preparation. By taking suitable precautions, solutions of tobacco mosaic virus can be made that show little or no anisotropy of flow and behave serologically more like somatic antigens; but these are unstable and readily change into anisotropic solutions with serological behaviour characteristic of flagellar antigens. This change seems to be connected with the removal of other material from the smaller nucleoprotein particles, which then join together end-to-end. The change in size and shape may explain the failure to produce true crystals of this virus *in vitro*, though they occur abundantly in infected plants.

We know also that the purified virus readily combines with other proteins such as trypsin and ribonuclease, and that these can be removed again without affecting infectivity. May not similar combinations occur within the host, and be responsible for converting this nucleoprotein into a functioning system capable of multiplication and of the activities of which the results are so obvious?

In addition to the changes produced by purification, there is other evidence that virus does occur in the plant in forms with different properties from those of the purified nucleoproteins. Until recently, all laboratory work on plant viruses was done with the sap that is expressed from macerated infected leaves. This

was thought to contain all the virus in the plant, for washing the fibrous residues gives little extra virus. However, these residues actually contain as much virus as does the sap ; but normally this is insoluble, probably because it is combined with other substances, and special treatments are needed to get it into solution. It is possible that this insoluble virus is the biologically active system, whereas that free in the sap may be merely excess virus functioning as a mobile source of infection for other cells. We know so little about the multiplication of viruses, and of their activities within the host, that at present we must suspend judgment. But it is probably safest to regard the nucleoproteins as the chemical minima—equivalent to reproductive organs or embryonic viruses—which develop into working entities only when placed in an environment containing the materials or enzyme systems they lack in their purified state.

## TROPICAL PASTURES *

The best grassland has depended for its existence upon a moderately cool and humid climate. Only a relative few of those familiar with the almost perpetual verdancy of English meadows and pastures realize the intensity of longing expressed in Psalm xxiii for *green* pastures and running waters seldom seen in a semi-arid land. In the tropics a high rainfall promotes the formation of acid soils, and a high temperature makes it difficult for most turfy grasses to form what inhabitants of temperate climates regard as a sward. Choice of tropical fodder plants is so limited that some varieties of sugar-cane are impressed into the class of forage grasses ; and most of the tropical grasses are either tall and erect, or trail to make a tangled cover, neither type of growth being so amenable as that of the grasslands of Great Britain or of the temperate lands colonized by European pasture-species.

The difficulties of establishing a pasture in the tropics are added to by an apparent lack of suitable leguminous companion plants : no legume having properties corresponding to wild white or subterranean clover has been found.

Two recent Bulletins (Nos. 31 and 32) of the Imperial Bureau of Pastures and Forage Crops at Aberystwyth deal with pasture problems. No. 31 is entirely, and No. 32 partly, devoted to problems of management in the warmer countries. No. 32 ("Advances in Grassland Husbandry and Fodder Production : a Symposium") is a miscellany, ranging from an appreciation (with bibliography) of the scientific work of R. D. Williams to a review of field experiments at Potchefstroom and a note on the fixed oil of the seeds of *Trifolium subterraneum*. The articles are mainly reviews or abstracts, the 'symposium' thus being a gathering of varied information which might not otherwise have been published, or, if published, might escape the attention which the compilers seem to think it deserves. There is no common thread of interest.

Under the title "The Provision of Animal Fodder in Tropical and Subtropical Countries : Part One" Bulletin No. 31 gives a succinct account of experience and hopes in the West Indies, Hawaii, Fiji, the Gold Coast, Nigeria, the Anglo-Egyptian Sudan, Zanzibar and Pemba, and Southern Rhodesia. The information it gives will be valuable not only from the purely grassland aspect but also from sociological points of view, since for example in West Africa the potentialities of change in the type of husbandry are of high social importance. That is also true of the West Indies, and indeed the paper written by D. D. Paterson with assistance from other West Indian authorities is a masterly presentation in brief of the whole problem implied by an extensive establishment of good grassland in the tropics.

To find species that would grow at all under the given conditions has been the first thing, and with limited experimental resources it has been natural to neglect matters like those which have not received full attention in more highly developed areas.

Quality of herbage, and its effect upon live-stock, is largely an open question in the tropics, few chemical analyses being available. Paterson remarks : "There can be no doubt that under tropical conditions the chances that the herbage may be lacking in some essential minor constituents are not less than in temperate countries. After a spell in some of the other islands, racehorses reared in Tobago do not stand up to the strain of the racecourse as well as they do in their home island". Pressure of research in other directions is given as the reason for deferment of intensive study of the rôle of minor elements ; but it seems fair to ask why the question of nutritional quality should be taken so fatalistically. The salary of a chemist or two would surely not be too much to add to an ordinary budget of chemical or veterinary investigation, and in conjunction with a rational policy of land use and nutrition would probably yield a high dividend.

The bulletin contains a large number of suggestive facts. Fiji has no native grass, the so-called 'native' grasses being importations which have run wild. In view of the decline of the natural indigo industry, it is interesting to learn that the cultivation of a trailing species of indigo for fodder and for purposes of soil protection is actually on the increase. What is a pest in one part of the world may be a useful grass in other parts of the world—or, as in Hawaii, in another part of one island.

* Article by Hugh Nicol reproduced from *Nature*, Vol. 154, No. 3921, 1945.

# THE OIL PALM RESEARCH STATION OF NIGERIA

BY

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The products of the Oil Palm (*Elaeis guineensis*, Jacq.) constitute two of the major agricultural exports of Nigeria, the export value of palm oil and palm kernels in a normal pre-war year being in the neighbourhood of £5,000,000. There is, in addition, a large internal consumption of palm oil estimated to be at least half of the total production, for it constitutes an article of great nutritional value in the dietary of the majority of the peoples of Southern Nigeria. Increasing quantities are also being railed from the South for the use of the peoples of the non-palm growing areas of Northern Nigeria.

The greater part of the palm oil and kernels produced in Nigeria comes from trees occurring wild in the farm lands and secondary bush which are harvested by the native farmer as and when bunches ripen. From these the oil is usually extracted by crude and wasteful methods leading to the production of an oil containing a high proportion of free fatty acid. A few large estates exist in Nigeria but their production is only a small percentage of the total.

From its inception, the Nigerian Agricultural Department has devoted considerable attention to improving the industry, both from the agricultural and from the oil extraction view-points and a considerable amount of work has been done on the Department's Experimental Stations in the Southern Provinces, in particular at Agricultural Headquarters, Ibadan. *During the 1930's, however, it became increasingly evident that the facilities available were not adequate: in particular, Ibadan was outside the oil palm belt proper and also the areas available on the existing Experimental Stations were too small to permit of any really extensive oil palm planting. It was therefore proposed to establish a new and separate station to deal exclusively with research on the oil palm.

## Situation

The first consideration was a suitable site for the station and choice was considerably narrowed by the large amount of land required, the total area included in the present station being 4,285 acres or over 6 square miles. To acquire such a large area of land in the palm growing areas of the Eastern Provinces would have proved exceedingly difficult if not impossible in view of the high density of population there and consequent shortage of land. The most likely area in the palm belt appeared to be somewhere in the Benin Province where the population was smaller and the acquiring of a suitable area consequently less difficult. Various possible sites were investigated and the final choice was made of an area of land situated in the Ekiadolor Forest Reserve of Benin Province.

This area is readily accessible from the main Benin-Ibadan road, the station being 18 miles from Benin and 224 from Ibadan. A plentiful supply of good water is assured from the Okhuo River which forms the Northern boundary of the station and suitable sites on high ground exist for housing.

## Soils and Climate

The station is situated on the Acid Benin Sands derived from Eocene formations. These soils are characterised by their intense acidity (pH generally less than 5), except where mineralisation of humus has led to a surface accumulation of bases, and they constitute the main soil type throughout the palm belt. They have a high content of coarse sand resulting in free and rapid drainage but are very deficient in bases, calcium, potash, &c. Also what phosphate there is appears to have a low availability. As a result these soils are generally markedly infertile.

The station is situated at approximately Latitude 6°35N and Longitude 5°40W and at an average height of 500 feet above sea level.

Rainfall records have been kept since 1940 and the annual rainfall over the period 1940-43 has averaged 75.18 inches ranging from a maximum of 94.43 inches to a minimum of 55.54. Distribution is markedly seasonal as the accompanying table shows.

| | *Average Rainfall Average Inches* 1940-43 |
|---|---|
| January | .87 |
| February | .49 |
| March | 2.46 |
| April | 5.73 |
| May | 8.03 |
| June | 12.85 |
| July | 12.69 |
| August | 7.25 |
| September | 12.54 |
| October | 8.94 |
| November | 3.20 |
| December | .13 |

Temperatures range from a maximum of 95°F to a minimum of 60°F with a daily average maximum of about 85°F and minimum of 70°F. The usual wet and dry bulb observations are taken and average evaporation is measured by a Piche Evaporimeter. Average humidity is high.

* A comprehensive account of this work up to 1938 has been given by Smith and Toovey (1).

(1) Investigation and Selection in the Oil Palm, E. H. G. Smith and F. W. Toovey, *Tropical Agriculture* 15 : 2 : 33-41, 1938.

So far no sunshine records have been kept but it is hoped to remedy this as soon as a suitable instrument can be secured.

On these soils and with this rainfall and temperature, the ecological climax is the tropical rain forest. Under these conditions a natural balance is struck between leaf fall and humic decay and fertility is maintained at a reasonable level.

Once the forest cover is cut down, however, as in native farming operations, fertility begins rapidly to decline and only two years' cropping is normally practised by the African farmer before he allows the land to revert to a bush fallow. This bush fallow, normally allowed to operate for 12 to 15 years is the surest way of restoring a measure of fertility to these soils though experiments with farm yard manure on the Departmental Stations have given promising results. The Benin Sands, being in general very deep, contain no parent rock which by weathering might restore mineral fertility.

The oil palm does not occur naturally to a very great extent in the mature forest, but where this has been cleared for some reason or other, seedlings become established and as the bush comes up again so does the palm, meeting intense competition from the surrounding vegetation as this once again develops towards its forest climax.

When acquired, the station was in secondary forest probably at least 50 years old, it having been previously part of a Forest Reserve.

### Layout

The site was surveyed in 1938 and the whole area laid out in 100 acre blocks orientated so that the sides lie north-south and east-west. The blocks are rectangular with sides of 800 yards and 605 yards respectively. Roads 24 feet wide run or will run east and west between each 100 acre block and north and south between each pair of blocks. One block has been earmarked for a Reservation Area where permanent European houses will be sited and a further 300 acres have been set aside for the building of a model African Village for African staff and labour after the war. A site has also been provisionally selected for a mill which will be necessary as the palms come into bearing and also for experimental purposes.

The necessity of having a station of such a large acreage is imposed by the nature of the oil palm. It is a tree crop normally planted at a spacing of 29 feet triangular giving 59 trees to the acre. In any experimental comparison, it is seldom possible to use a smaller plot size than 16 palms or one-fourth acre and in modern statistical layouts involving suitable guard rows and adequate replications the size of any experiment can seldom be less than 10 acres and the largest so far laid down requires 120 acres. Consequently, 4,000 acres for a long term station of this nature is by no means excessive.

A point to be noted here is that as it would be inadvisable to translate results obtained on O.P.R.S. direct to other areas in the palm belt, particularly the Eastern Provinces where a sub-station is envisaged on which the more important agricultural and breeding work will be repeated. This sub-station will probably comprise a few hundred acres in the Calabar Province wherever land availability and general conditions should permit. The opening of such a sub-station must however be indefinitely postponed until such time as staff and requisite funds are available.

### Policy

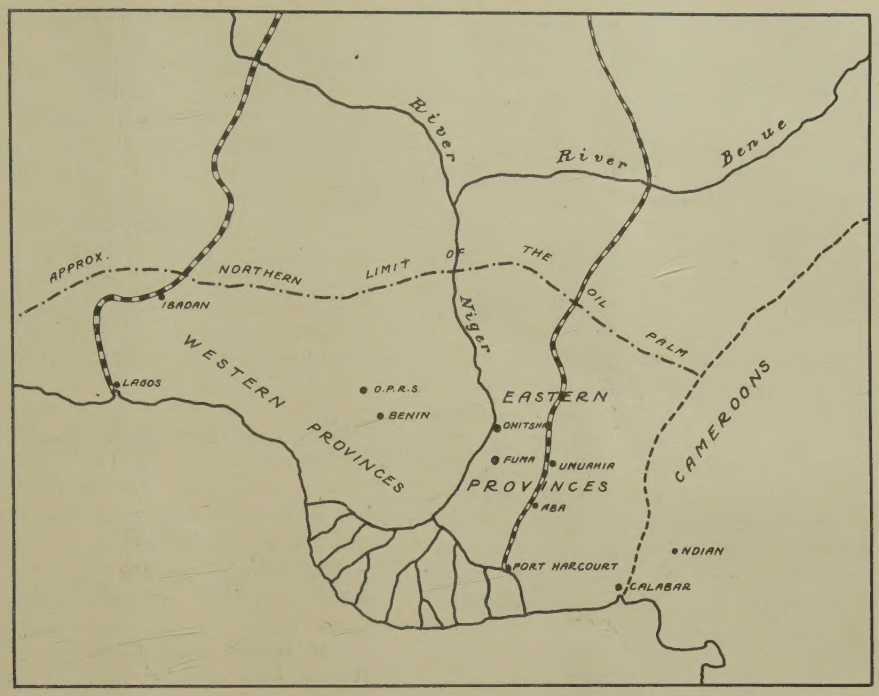
Useful information on some of the lines of work to be followed was secured on a visit to the Yangambi Research Station of the Institut National pour les Etudes Agronomiques du Congo Belge by Mr. Toovey, Botanist of the Department in 1938. The three practical considerations are firstly to determine the most efficient means of cultivating the oil palm, both from the point of view of the small African farmer and the estate; secondly, to select and breed for improved high yielding types of palms and to arrange for the production on a large scale of these improved types for distribution; and lastly, to conduct research into the best methods of extracting palm oil and kernels from the fruit. To these ends must also be included fundamental researches into the genetics, physiology, &c., of the palm. The actual programme of work is directed by an Advisory Committee which meets at Agricultural Headquarters, Ibadan, once a year and this Committee is comprised of the Director of Agriculture or the Assistant Director, the Senior Botanist, Southern Provinces, the Botanist, O.P.R.S., the Agricultural Officer, O.P.R.S. (if staffing permits the appointment) and the Senior Agricultural Officer, Eastern Provinces. This meeting is usually preceded by a Conference of other Agricultural Officers and Botanists at which a more general discussion of points in connection with the oil palm is possible and which puts up recommendations to the Advisory Committee.

### Organisation

Some account of the present war-time organisation of the station may be of interest. Resident on O.P.R.S. is a European Botanist responsible for all the work on the main station and the various activities at the outstations. He usually visits these outstations twice a year to check up on the general routine and supervision.

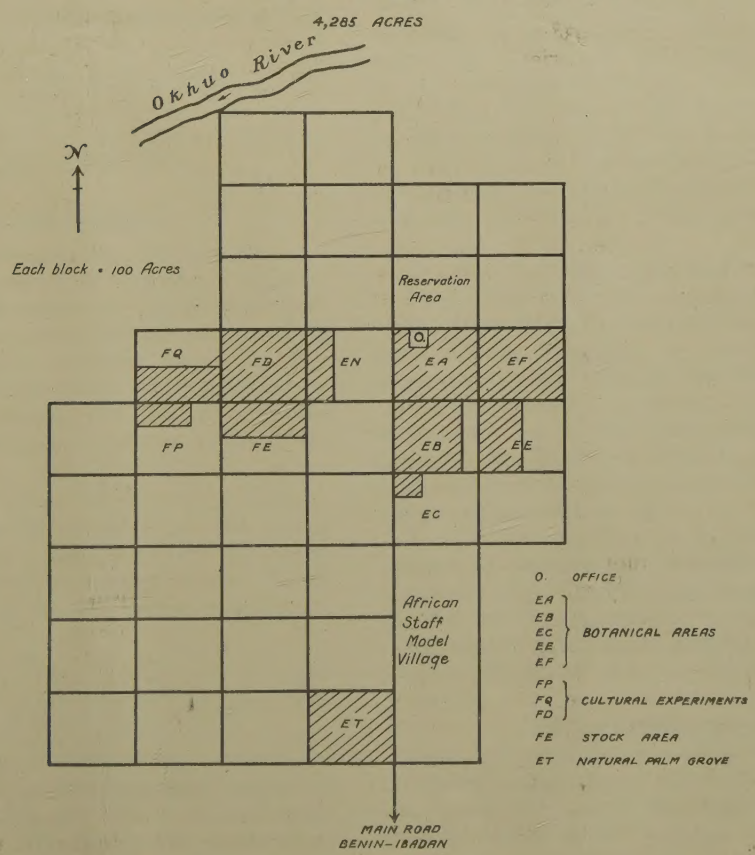
The greater part of the routine work on O.P.R.S. devolves on the African staff, the general running of the station, management of labour, &c., being in the hands of an Assistant Agricultural Officer. Three Agricultural Assistants are in charge of botanical, agricultural and chemical work and they control a subordinate grade of eight Field Overseers. Four clerks are responsible for office work including the summarising and tabulating of the vast quantity of data being amassed at the main station and outstations.

At the outstations (under the Agricultural Officer in charge) are posted either Agricultural Assistants or Field Overseers depending upon the importance and complexity of the experimental work being undertaken.




SOUTHERN NIGERIA

## OIL PALM RESEARCH STATION



### Experimental Work

While it is not intended, nor possible, to give within the scope of this short paper, a full account of experimental work in progress at O.P.R.S. a short account will be inserted, full details being given in the Annual Reports of the station.

### Agricultural Experiments

These include experiments on the viability of seed in storage, germination of ripe *versus* unripe fruit and germination of interior fruit from a bunch as against exterior fruit ; nursery experiments to reduce disease and dry season losses by shading, watering, &c.

The best method of treating palm seedlings before transplanting to the field involving varying degrees of leaf and root pruning.

The advisability or otherwise of burning the felled bush in the field in establishing a plantation.

The most efficient and economical method of establishing a palm plantation, the treatments including intercropping with annual food crops, maintaining a low or high bush cover and a planted leguminous cover.

The optimum spacing for planted palms, with particular reference to the possibility of planting food crops or grazing cattle between the palms in later years.

The effect of dressings of farm yard manure, lime and wood ash applied annually to the palms.

The most suitable treatment of wild palm groves to improve their yields.

It will be many years before the results of most of these experiments become apparent but most detailed records are kept of the rates of growth and yields of each experimental palm.

### Selection and Breeding

The classic selection area for Nigeria was the small plantation at Calabar established in 1913 to 1915 with seed from ordinary thick-and thin-shelled types and the green-fruited and mantled types. Progenies from selected trees in the plantation have been planted in large numbers on the Experimental Farms at Ibadan, Benin, Onitsha and Umuahia and also more recently on O.P.R.S.

Further selection areas on which individual yield recording is carried out exist at Aba where a group of wild palms contains several promising yielders, a similar group at Ufuma and at Ndian on planted palms of the United Africa Company's estate.

In all some 30,000 palms are being recorded for yield including those trees marked for selection and trees in other experimental layouts.

The selection standards are being constantly improved, but as it is, a well organised system of seed production from selected trees has been under way for several years. The high yielding selections are artificially interpollinated and in 1943-44 a total of 430,000 seeds was produced on the Experimental Stations at Benin, Onitsha and Umuahia for germination and eventual distribution as seedlings to farmers wishing to establish palm plantations.

Large numbers of progenies of known parents have been planted up in progeny trials for studies of inheritance of yield, fruit type and form and included in the botanical plantings are trials of cross versus self-pollinated progenies, a uniformity trial and a comparison of imported Deli trees with selected Nigerian types.

### Chemical Investigations

A small chemical laboratory has been built on O.P.R.S. and routine analyses are made of soil samples from certain experiments. Weekly samples are taken and analysed for moisture and nitrate content.

In addition experiments are being done with a Miller hand press, as used by increasing number of African farmers, to determine the optimum treatment of palm fruit before extracting to ensure a minimum of free fatty acid content. Work is proceeding on the analysis of bunch samples for determining sampling error in moisture and oil determination on fruit.

### Outstations

Besides the work described above being done on the main station and the selection work at Calabar, Aba and Ufuma, cultural and manurial experiments are also proceeding at Ibadan, Benin, Onitsha, Umuahia and Aba. Some of these experiments deal with particular problems of the area, at Onitsha for example, manurial experiments are being conducted to try to counteract the effect of the yellowing disease which affects older palms in that area. These experiments are all under the control of the main station to which all yields and data are sent for tabulation and analysis.

### Other Activities

To produce farm yard manure for experimental work a small herd of dwarf West African Short-horn cattle, resistant to try-panosomiasis, is maintained. By running an improved N'dama bull with this herd an attempt is also being made to increase the size of these beasts. It is hoped to train the cross-bred bullocks to pull carts and help to cope with the transport of palm fruit as the palms come into bearing.

A collection of as many members of the family Palmae as possible has been made and there are also small plots of various economic crops including a citrus orchard, mangoes, cocoa, rubber, &c.

All timber used on the station is pit-sawn from trees felled in the course of clearing operations.

### Future Development

From its inception the station has been financed by the Nigerian Government but application has been made for a grant from the Colonial Development and Welfare Fund to provide more adequate funds. At present all housing and offices are of a

temporary nature and considerable capital expenditure is called for to provide adequate housing and amenities for the European and African staff. These will include a pumped water supply from the Okhuo River, telephone communications, and an electricity supply. Well equipped laboratories are also called for and, a limiting feature, more trained staff, both European and African.

The problems to be tackled are many including studies of a physiological, cytological and mycological nature, studies which formerly were considered academic but are now realised to be an integral part of that complex technique known as plant breeding.

**Acknowledgments**

It would be impossible to acknowledge by name all those who have contributed to the establishment of the Oil Palm Research Station but my indebtedness is due in particular to Messrs. Sheffield, Toovey, and Campbell of the Agricultural Department for information taken from their early Annual Reports of the Station, and especially to Mr. Toovey for criticism in preparing this paper.

Finally my grateful acknowledgments to Captain J. R. Mackie, C.M.G., Director of Agriculture for permission to publish this paper.

## CHEMICAL NOTES

*(Compiled by the College Department of Chemistry and Soil Science)*

### Most Suitable Temperatures of Rotting in the Manure Heap

An article in *Forsch Dienst. Sonderh.* 17, 1941 (103-109), discusses the properties of manure rotted at low, medium and high temperatures with and without free access of air, from the point of view of the distinction between "permanent" and "nutrient" humus in soil, and in the heap. An analytical note is added on the determination of degree of rotting by means of $H_2O_2$ as distinct from determination of the humus content of manure by means of acetyl bromide. Anaerobic decomposition produces an acid manure, aerobic an alkaline manure. In presence of much straw a weak acid reaction may arise even under aerobic conditions. Loss of nitrogen and dry matter is higher under aerobic conditions and is greatest at temperatures of 45-50°C. Accumulation of permanent humus (insoluble in a etyl bromide) is also greatest at 45-50°C. It is concluded that the two most favourable temperatures for rotting manure heaps lie between 30 and 40°C, and between 50 and 60°C. —(*Soils and Fertilizers*, VII, 4, 1944).

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### Coffee By-Products

A Swedish inventor is said to have devised a method of extracting large quantities of products from coffee—not only caffeine, fat, and tannin, but also lubricating oils and different kinds of phenols and hydrogen. After the caffeine has been extracted, the ground coffee is mixed with calcium oxide and small quantities of two catalysts. The mixture is heated in an oven at about 500°C, and the resulting gas passed through a series of condensers, the different materials becoming separated one after another by means of distillation and decantation. The inventor has found that the following products can be obtained from 5,070 pounds of unroasted coffee: in the first stage of the process—53 pounds of caffeine, 529 pounds of fat, and 88 pounds of tannin; during the second stage—227 pounds of acetone, 97 pounds of methyl alcohol, 53 pounds of phenol (carbolic acid), 368 pounds of raw oil, 672 pounds of lubricating oil and ammonia, and 520 to 650 cubic yards of hydrogen gas.

The oil extracts vary from the lightest to the heaviest qualities. They are raw oils which are said to be suitable for use in motor cars or airplanes. Some of them have a fuel value of more than 10,000 calories. Since the hydrogen gas obtained supplies the necessary vapour for the process, the total costs of production are small.—(*Agriculture in the Americas*, IV, No. 12, 1944.)

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### Maintenance of Soil Fertility in Areas devoid of Livestock in Northern Rhodesia

Since the war began experimental work has been reduced to a minimum in order to free the available staff for food production and reclamation work. One result may, however, form the solution, if perhaps a laborious one, to the problem of maintaining soil fertility in areas devoid of livestock. At Lunzuwa a randomized plot experiment yielded the following results:

(*a*) No compost series (control) 4 bags maize per acre.

(*b*) Green grass and leaves compost series 12½ bags maize per acre.

(*c*) Green and old grass compost series 11¾ bags maize per acre.

(*d*) Sheep compost series 13½ bags maize per acre.

The differences between the several compost series were insignificant but all treatments were definitely superior to the control. The rate of dressing was too high for practical purposes—25 tons per acre—and this may have masked differences between the various composted plots. It does appear, however, that by using the high nitrogen content of young green grass a very satisfactory compost can be made without animal agency. The experiment confirmed the opinion formed from observations on plots of wheat, similarly treated, in the preceding season.—(*Soils and Fertilizers*, VII, 4, 1944. From 1943 *Ann. Rept. of the Northern Rhodesia Dept. of Agriculture*).